

1. (Original) A facial expression transformation method comprising:  
defining a code book containing data defining a first set of facial  
expressions of a first person;

providing data defining a second set of facial expressions, the second set of  
facial expressions providing a training set of expressions of a second person who  
is different from the first person;

deriving a transformation function from the training set of expressions and  
corresponding expressions from the first set of expressions; and

applying the transformation function to the first set of expressions to  
provide a synthetic set of expressions.

2. (Original) The method of claim 1, wherein the training set of  
expressions contains fewer expressions than the code book.

3. (Original) The method of claim 1, wherein the transformation  
function compensates for differences in the size and shape of the faces of the first  
and second persons.

4. (Original) The method of claim 1, wherein said deriving of the  
transformation function comprises computing a linear transformation from one set  
of expressions to another.

5. (Original) The method of claim 1, wherein the deriving of the  
transformation function comprises:

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1 representing each expression as a  $3m$ -vector that contains  $x$ ,  $y$ ,  $z$   
2 displacements at  $m$  standard sample positions; and

3 computing a set of linear predictors  $a_j$ , one for each coordinate of  $g_a$ , given  
4 a set of  $n$  expression vectors for a face to be transformed,  $g_{a1...n}$ , and a  
5 corresponding set of vectors for a target face,  $g_{b1...n}$ , by solving  $3m$  linear least  
6 squares systems of the following form:

$$a_j \cdot g_a = g_{b1}[j], i = 1...n$$

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9 6. (Canceled).

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11 7. (Canceled).

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13 8. (Canceled).

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15 9. (Canceled).

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17 10. (Original) The method of claim 1, wherein said providing data  
18 defining a second set of facial expressions comprises:

19 illuminating the second person's face with illumination; and

20 contemporaneously capturing structure data describing the face's structure  
21 and reflectance data describing reflectance properties of the face from the  
22 illumination.

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24 11. (Canceled).

1 12. (Canceled).

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3 13. (Canceled).

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5 14. (Canceled).

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7 15. (Canceled).

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9 16. (Canceled).

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11 17. (Canceled).

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13 18. (Canceled).

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15 19. (Original) One or more computer-readable media having computer-  
16 readable instructions thereon which, when executed by a computer, cause the  
17 computer to:

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18 operate on a training set of expressions from one person and corresponding  
19 expressions from a code book of another person to compute a linear  
20 transformation function from the training set and their corresponding expressions;  
21 and

22 apply the transformation function to a plurality of expressions from the  
23 code book to provide a synthetic set of expressions.  
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1           20. (Original) The computer-readable media of claim 19, wherein the  
2 instructions cause the computer to use the synthetic set of expressions to transform  
3 expressions from the one person into expressions of the other person.

4  
5           21. (Original) The computer-readable media of claim 20, wherein the  
6 instructions cause the computer to transform expressions from the one person that  
7 are different from those expressions comprising the code book expressions.

8  
9           22. (Original) The computer-readable media of claim 20, wherein the  
10 instructions cause the computer to transform expressions by transmitting at least  
11 one index of a synthetic expression to a receiver that can reconstruct the  
12 expression.

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14           23. (Original) The computer-readable media of claim 20, wherein the  
15 instructions cause the computer to transform facial expressions.

16  
17           24. (Original) A facial expression transformation system comprising:  
18 a code book embodied on a computer-readable medium, the code book  
19 containing data defining a first set of facial expressions of a first person;  
20 data embodied on a computer-readable medium, the data defining a second  
21 set of facial expressions, the second set of facial expressions providing a training  
22 set of expressions of a second person who is different from the first person; and  
23 a transformation processor configured to derive a transformation function  
24 from the training set of expressions and corresponding expressions from the first  
25 set of expressions.

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2 25. (Original) The expression transformation system of claim 24,  
3 wherein the transformation processor comprises a linear transformation processor.

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5 26. (Original) The expression transformation system of claim 24 further  
6 comprising a synthetic set of expressions embodied on a computer-readable  
7 medium, the synthetic set of expressions being derived by applying the  
8 transformation function to the code book expressions.

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10 27. (Original) The expression transformation system of claim 24,  
11 wherein the transformation function compensates for differences in the size and  
12 shape of the faces of the first and second persons.

13  
14 28. (Original) The expression transformation system of claim 24,  
15 wherein the transformation processor derives the transformation function by:

16 representing each expression as a  $3m$ -vector that contains  $x$ ,  $y$ ,  $z$   
17 displacements at  $m$  standard sample positions; and

18 computing a set of linear predictors  $a_j$ , one for each coordinate of  $g_m$  given  
19 a set of  $n$  expression vectors for a face to be transformed,  $g_{a1...n}$ , and a  
20 corresponding set of vectors for a target face,  $g_{b1...n}$ , by solving  $3m$  linear least  
21 squares systems of the following form:

22 
$$a_j \cdot g_m = g_{b[j]}, i = 1...n$$

23  
24 29. (Original) A facial expression transformation system comprising:  
25 a transmitter comprising:

1 a facial illumination system that is configured to provide multiple different  
2 light sources at the same time for illuminating a subject's face;

3 a data-capturing system configured to capture both structure data and  
4 reflectance data from the subject's face when illuminated by the facial  
5 illumination system; and

6 a first code book of synthetic expressions that have been synthesized by:  
7 receiving a training set of expressions provided by the subject;  
8 computing a transformation function using the training set of expressions  
9 and corresponding unsynthesized code book expressions; and

10 applying the transformation function to all of the expressions in the code  
11 book; and

12 a receiver communicatively linked with the transmitter and comprising:

13 a reconstruction module for reconstructing facial images; and

14 a second code book containing the same synthetic expressions as the first  
15 code book; and

16 the transmitter being configured to:

17 capture additional expressions of the subject;

18 search the first code book for a corresponding or near matching expression;

19 and

20 transmit an index of a corresponding or matching code book expression to  
21 the receiver for facial image reconstruction by the reconstruction module.

22  
23 30. (Original) The expression transformation system of claim 29,  
24 wherein the illumination system comprises at least one polarized light source.  
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1           31. (Original) The expression transformation system of claim 29,  
2 wherein the illumination system comprises multiple polarized light sources.

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4           32. (Original) The expression transformation system of claim 29,  
5 wherein the illumination system comprises a patterned light source configured to  
6 project a pattern onto the subject's face.

7  
8           33. (Original) The expression transformation system of claim 29,  
9 wherein the illumination system comprises an infrared patterned light source  
10 configured to project a pattern onto the subject's face.

11  
12           34. (Original) The expression transformation system of claim 29,  
13 wherein the different light sources are all infrared light sources.

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15           35. (Original) A method of animating facial features comprising:  
16 defining a subdivision surface that approximates geometry of a plurality of  
17 different faces; and  
18 fitting the same subdivision surface to each of the plurality of faces.

19  
20           36. (Original) The method of claim 35, wherein said defining comprises  
21 defining the subdivision surface with a coarse mesh structure.

22  
23           37. (Original) The method of claim 36, wherein the coarse mesh  
24 structure comprises a triangular mesh.  
25

1 38. (Original) The method of claim 35, wherein said fitting comprises  
2 performing a continuous optimization operation over vertex positions of the  
3 subdivision surface.

4  
5 39. (Original) The method of claim 35, wherein said fitting comprises  
6 fitting the subdivision surface to the faces without altering the connectivity of a  
7 mesh that defines the subdivision surface.

8  
9 40. (Original) The method of claim 35, wherein said fitting comprises  
10 minimizing a smoothing functional associated with a mesh that defines the  
11 subdivision surface.

12  
13 41. (Original) The method of claim 35, wherein said fitting comprises  
14 selecting one or more constraints associated with a mesh that defines the  
15 subdivision surface and fitting those constraints directly to corresponding points  
16 on the faces.

17  
18 42. (Original) The method of claim 41, wherein the constraints are  
19 associated with one of the eyes, nose and mouth.

20  
21 43. (Original) The method of claim 35, wherein said fitting comprises  
22 minimizing a functional that includes terms for distance, smoothness, and  
23 constraints.

24

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1 44. (Original) The method of claim 35, wherein said fitting comprises  
2 solving a sequence of linear least-squares problems.  
3

4 45. (Original) One or more computer-readable media having computer-  
5 readable instructions thereon which, when executed by one or more computers,  
6 cause the one or more computers to implement the method of claim 35.  
7

8 46. (Original) A method of animating facial features comprising:  
9 defining a subdivision surface that approximates geometry of a plurality of  
10 different faces;  
11

12 fitting the same subdivision surface to each of the plurality of faces to  
13 establish a correspondence between the faces; and  
14

15 using the correspondence between the faces to transform an expression of  
16 one face into an expression of another face.  
17

18 47. (Original) A method of animating facial features comprising:  
19 measuring 3-dimensional data for a plurality of different faces to provide  
20 corresponding face models;  
21

22 defining only one generic face model that is to be used to map to each  
23 corresponding face model;  
24

25 selecting a plurality of points on the generic face model that are to be  
mapped directly to corresponding points on each of the corresponding face  
models; and

1 fitting the generic face model to each of the corresponding face models,  
2 said fitting comprising mapping each of the selected points directly to the  
3 corresponding points on each of the corresponding face models.

4  
5 48. (Original) The method of claim 47, wherein:

6 said defining comprises defining a subdivision surface from a base mesh  
7 structure, the subdivision surface containing a plurality of vertices and  
8 approximating the geometry of the face models; and

9 said fitting comprises manipulating only the positions of the vertices of the  
10 subdivision surface.

11  
12 49. (Original) The method of claim 47, wherein said fitting comprises  
13 manipulating a base mesh that defines a subdivision surface.

14  
15 50. (Original) The method of claim 47, wherein said fitting comprises  
16 manipulating a base mesh that defines a subdivision surface without altering the  
17 connectivity of the base mesh.

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19 51. (Original) The method of claim 47, wherein said measuring  
20 comprises using a laser range scan to measure the 3-dimensional data.

21  
22 52. (Re-presented—formerly dependent claim 6) A facial expression  
23 transformation method comprising:

24 defining a code book containing data defining a first set of facial  
25 expressions of a first person;

1 providing data defining a second set of facial expressions, the second set of  
2 facial expressions providing a training set of expressions of a second person who  
3 is different from the first person;

4 deriving a transformation function from the training set of expressions and  
5 corresponding expressions from the first set of expressions, wherein the deriving  
6 of the transformation function comprises:

7 representing each expression as a  $3m$ -vector that contains  $x$ ,  $y$ ,  $z$   
8 displacements at  $m$  standard sample positions; and

9 computing a set of linear predictors  $a_j$ , one for each coordinate of  $g_a$ ,  
10 given a set of  $n$  expression vectors for a face to be transformed,  $g_{a1...n}$ , and a  
11 corresponding set of vectors for a target face,  $g_{b1...n}$ , by solving  $3m$  linear  
12 least squares systems of the following form:

$$13 \quad a_j \cdot g_a = g_b[j], i = 1 \dots n,$$

14 wherein said computing comprises using only a subset of points for  
15 each  $g_{aj}$ ; and

16 applying the transformation function to the first set of expressions to  
17 provide a synthetic set of expressions.

18  
19 53. (Re-presented—formerly dependent claim 7) The method of claim  
20 52, wherein said using comprises using only points that share edges with a  
21 standard sample point under consideration.

22  
23 54. (Re-presented—formerly dependent claim 8) A facial expression  
24 transformation method comprising:  
25

1 defining a code book containing data defining a first set of facial  
2 expressions of a first person;

3 providing data defining a second set of facial expressions, the second set of  
4 facial expressions providing a training set of expressions of a second person who  
5 is different from the first person;

6 deriving a transformation function from the training set of expressions and  
7 corresponding expressions from the first set of expressions, wherein the deriving  
8 of the transformation function comprises:

9 representing each expression as a  $3m$ -vector that contains  $x$ ,  $y$ ,  $z$   
10 displacements at  $m$  standard sample positions; and

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11 computing a set of linear predictors  $a_j$ , one for each coordinate of  $g_a$ ,  
12 given a set of  $n$  expression vectors for a face to be transformed,  $g_{a1...n}$ , and a  
13 corresponding set of vectors for a target face,  $g_{b1...n}$ , by solving  $3m$  linear  
14 least squares systems of the following form:

$$a_j \cdot g_a = g_b[j], i = 1...n;$$

15  
16 controlling the spread of singular values when computing a  
17 pseudoinverse to solve for the  $a_j$ ; and

18 applying the transformation function to the first set of expressions to  
19 provide a synthetic set of expressions.

20  
21 55. (Re-presented—formerly dependent claim 9) The method of claim  
22 54, wherein said controlling the spread comprises zeroing out all singular values  
23 less than  $\alpha\sigma_1$ , where  $\sigma_1$  is the largest singular value of the matrix.

1 56. (Re-presented—formerly dependent claim 11) A facial expression  
2 transformation method comprising:

3 defining a code book containing data defining a first set of facial  
4 expressions of a first person;

5 providing data defining a second set of facial expressions, the second set of  
6 facial expressions providing a training set of expressions of a second person who  
7 is different from the first person, wherein said providing data defining a second set  
8 of facial expressions comprises:

9 illuminating the second person's face with illumination, said  
10 illuminating comprising:

11 using multiple light sources, one of which projecting a pattern on the  
12 second person's face from which the structure data can be ascertained;

13 at least one of the light sources comprising an infrared light source;

14 at least one of the light sources being polarized; and

15 contemporaneously capturing structure data describing the face's  
16 structure and reflectance data describing reflectance properties of the face  
17 from the illumination, said capturing comprising using a camera having a  
18 polarizer that suppresses specularly-reflected light so that diffuse  
19 component reflection data is captured;

20 deriving a transformation function from the training set of expressions and  
21 corresponding expressions from the first set of expressions; and

22 applying the transformation function to the first set of expressions to  
23 provide a synthetic set of expressions.  
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1 57. (Re-presented—formerly dependent claim 12) A facial expression  
2 transformation method comprising:

3 defining a code book containing data defining a first set of facial  
4 expressions of a first person;

5 providing data defining a second set of facial expressions, the second set of  
6 facial expressions providing a training set of expressions of a second person who  
7 is different from the first person, , wherein said providing data defining a second  
8 set of facial expressions comprises:

9 illuminating the second person's face with a first polarized light  
10 source that is selected so that specularly-suppressed reflective properties of  
11 the face can be ascertained;

12 illuminating the second person's face with a second structured light  
13 source that projects a pattern onto the face, while simultaneously  
14 illuminating the face with the first polarized light source; and

15 capturing both specularly-suppressed reflection data and structure  
16 data from the simultaneous illumination;

17 deriving a transformation function from the training set of expressions and  
18 corresponding expressions from the first set of expressions; and

19 applying the transformation function to the first set of expressions to  
20 provide a synthetic set of expressions.

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22 58. (Re-presented—formerly dependent claim 13) The method of claim  
23 57, wherein the light sources provide light at different frequencies.  
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1 59. (Re-presented—formerly dependent claim 14) The method of claim  
2 57, wherein the light sources provide infrared light.

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4 60. (Re-presented—formerly dependent claim 15) The method of claim  
5 57, further comprising processing the captured data to provide both (a) data that  
6 describes dimensional aspects of the face and (b) data that describes diffuse  
7 reflective properties of the face.

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11 61. (Re-presented—formerly dependent claim 16) A facial expression  
12 transformation method comprising:

13 defining a code book containing data defining a first set of facial  
14 expressions of a first person;

15 providing data defining a second set of facial expressions, the second set of  
16 facial expressions providing a training set of expressions of a second person who  
17 is different from the first person, wherein said providing data defining a second set  
18 of facial expressions comprises:

19 illuminating the second person's face with multiple different light  
20 sources;

21 measuring range map data from said illuminating;

22 measuring image data from said illuminating;

23 deriving a 3-dimensional surface from the range map data;

24 computing surface normals to the 3-dimensional surface; and

25 processing the surface normals and the image data to derive an  
albedo map;

1 deriving a transformation function from the training set of expressions and  
2 corresponding expressions from the first set of expressions; and  
3 applying the transformation function to the first set of expressions to  
4 provide a synthetic set of expressions.  
5

6 62. (Re-presented—formerly dependent claim 17) The method of claim  
7 61, wherein at least one of the light sources is polarized.

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9 63. (Re-presented—formerly dependent claim 18) The method of claim  
10 61, wherein all of the light sources are polarized.  
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